New Homes

Alberta Energy $avers — One of a Series

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New Homes

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Contents

What is an Energy Efficient Home?

An energy efficient home is more than a collection of individually efficient parts. It is a system that must work as a whole. Planning how the parts will fit together is crucial to building a home that is safe, reliable and efficient.

Energy efficient homes can look like any other homes in your neighborhood. The elements that save energy are hidden in their foundations, walls, ceilings and mechanical systems. These elements add seven to 10 per cent to construction costs, but they will give you a more comfortable home with fuel bills 35 to 55 per cent lower than a conventional house.

The key elements of an energy efficient home are:

- high insulation levels
- careful sealing for airtightness
- controlled ventilation
- a properly sized and controlled heating system
- properly designed windows in well-chosen locations

You have lots of choice about how to incorporate these elements and to what degree. Energy efficient homes range from well-insulated to super-insulated, from mostly fuel-heated to mostly solar-heated. They can be built with a variety of framing and sealing techniques, foundation and window types, and heating and ventilating systems.

This booklet is about choices in energy efficient home design and the building science basics they must respect. It begins by looking at the advantages of energy efficiency and then reviews basic design decisions, each element of energy efficient construction, alternative framing systems, and economics.

Energy efficient housing is an innovative response to our northern climate that is developing rapidly and catching on fast. We know, for example, that under the federal R2000 program, a leader in the field of low energy housing, 20 000 certified homes are planned by 1990 across Canada and that countless other similar homes will be built outside the program. As more homes are built, more techniques and products become available. If you are planning an energy efficient home, you are part of an exciting movement in Canadian housing.

Why Build an Energy Efficient Home?

Energy efficient homes have comfort, health and safety advantages over conventional homes. They also have smaller utility bills. Alberta's gas prices, however, make many construction techniques described in this booklet uneconomic. The techniques are included because economics is not the only reason to choose an energy efficient home.

Energy efficient homes are more comfortable than conventional homes because of their high levels of insulation and careful air sealing. A well-insulated home is warmer in winter and cooler in summer. People who live in energy efficient homes also find them quieter because insulation acts as soundproofing.

Airtightness means fewer drafts, less dust and better control over indoor air quality. While conventional homes rely on haphazard air leaks for fresh air, well-sealed homes use "forced" or mechanical ventilation which can be controlled and monitored. People who live in energy efficient homes list better indoor air quality as a comfort and health advantage.

Air supply to fuel-burning appliances receives particular attention in energy efficient homes to ensure their safe operation. The possibility of harmful gases escaping into your house because of inadequate ventilation for these appliances is very low. Some homes are built with heating systems that eliminate the risk altogether.

Comfort, health and safety are important advantages that may outweigh economics as reasons to build an energy efficient home. The economics of energy efficiency, however, will improve in the long run as energy prices rise. Building your home energy efficiently now is easier and much less expensive than trying to improve it later.

Basic Design Decisions

Planning your house involves a series of connected decisions, as Figure 1 illustrates. The central decisions are about basic house design: how energy efficient it will be, how much it will rely on passive solar heating and what floor plan it will use.

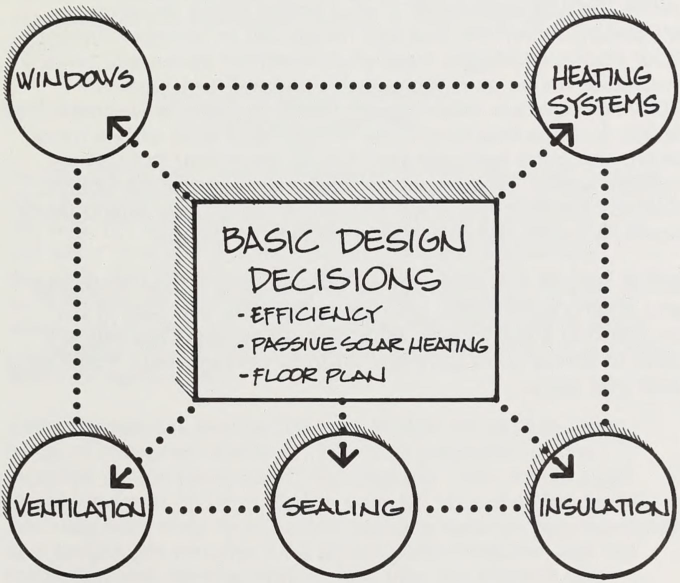


Figure 1 Connected Decisions in Planning a Home

The more energy efficient your home, the more it will cost to build. On the other hand, it will save more fuel and be more comfortable. The best trade-off for you depends on your finances and priorities.

Any home with south-facing windows can benefit from passive solar heating. To maximize solar heating, more windows should be placed on the south and fewer on the north. Windows facing due south gain the most heat. Windows oriented 30 degrees off south will achieve 90 per cent of the gains of a south-facing window; east- and west-facing windows achieve about 40 per cent. To avoid overheating, south-facing windows should add up to no more than 10 per cent of floor area in an energy efficient home, unless the design incorporates a heat storage mass such as a masonry wall. Too many west and southwest windows can also cause overheating due to the late afternoon sun.

While the size and shape of your house affect its energy efficiency, remember that any house can be energy efficient. Your floor plan should meet your needs for space and privacy. A smaller house uses less energy and will also save on building materials (each square metre you trim is worth $450 to $600). A shape that minimizes exterior wall area will be more energy efficient because your house loses heat through its outside walls. The closer your floor plan approaches square, the less exterior wall it will require. A rectangular shape facing south, however, takes better advantage of the sun.

Some special features such as overhanging floors, fireplaces and sliding patio doors are hard to insulate and seal. If you incorporate these in your floor plan, remember that you will have to spend extra time and effort to prevent them from being cold and leaky.

Elements of Energy Efficient Construction

Basic design decisions lead to choices about how to incorporate the five key elements of energy efficient construction and to what degree. This section reviews building science principles for each element and the relationship of each element to other planning decisions.

Insulation

Principles
Insulation reduces heat loss through the ceiling, exterior walls, windows, doors and foundation of your home to the outside. This form of heat loss is usually described as "heat flow through the building envelope." Heat flow increases as the area of the building envelope and the temperature difference between indoors and out becomes larger; it decreases as the resistance of the building envelope to heat flow becomes higher.

$$\text{heat flow} = \frac{\text{area x temperature difference}}{\text{resistance to heat flow}}$$

Resistance to heat flow is measured in RSI values (to convert RSI values to R values, multiply by 5.678). The more insulation you add, the less heat you lose. In fact, you cut heat flow in half each time you double insulation values. Remember, however, that the amount of energy you save will be less with each increment. For example, if an attic insulated to RSI 1 loses $180 of heat per year, doubling the insulation to RSI 2 would save $90. Doubling again to RSI 4, however, would only save half again or $45.

Attic Insulation, another booklet in this series, describes types of insulation available. The best insulation to use depends on the application; for example, only certain rigid insulations can be used for the exterior of foundation walls. You may also want to consider qualities such as fire resistance and weight per volume. As a general rule, however, use the insulation and framing system that lets you achieve your insulation objectives at least cost.

To be effective, insulation must be installed at an even thickness, without gaps, and to its design density. It must be protected with a vapour retarder and a continuously sealed air barrier to prevent moisture from entering and condensing inside the insulated cavity. Proper ventilation in attics and crawl spaces will also help control condensation by removing any moisture that does enter. In addition, ventilating your attic can control overheating in summer.

Connected Decisions
As you consider insulation levels for your home, remember to think about:

- **Insulation levels in the total building envelope.** Your house is a system of integrated components. If you choose high insulation levels for one part, you should balance that decision with high levels in other parts. Table 1 outlines some examples of balanced alternatives.

Table 1
Balanced Insulation Levels

House Component	House Type		
	Standard RSI (R)	Well-insulated RSI (R)	Super-insulated RSI (R)
foundation	2.1 (12)	3.5 (20)	4.9 (28)
basement floor	0.0	0.9 (5)	1.8 (10)
main walls	3.5 (20)	4.9 (28)	7.0 (40)
ceiling	6.0 (34)	7.0 (40)	10.6 (60)
windows	0.4 (2)	0.6 (3.2)	0.6 (3.2)

- **Type of framing systems.** Some framing systems are designed for high levels of insulation. Double walls and wall trusses, for example, are best for walls of RSI 7 (R 40) or better, and ceiling trusses can be built for any level of insulation. Choose the combination of framing systems that best suits your insulation objectives. In the construction details that follow in the next section, note that the system you choose will affect the location of your vapour retarder and the method of insulating your joist space.

- **Size and type of heating system.** The higher your insulation levels, the less heating capacity you need. The small heat requirements of energy efficient homes make more heating options practical, such as electric or fuel-fired space heaters.

Sealing for Airtightness

Principles

Energy efficient new homes should be sealed well to prevent heat loss from air leaks and to stop moisture from collecting in insulated spaces. Unless controlled, moisture will enter insulated spaces in two ways: 1) air movement that allows warm moist interior air to move through the building envelope, and 2) vapour pressure that causes moisture to diffuse through the envelope, independent of air movement.

Air movement is by far the most important mechanism and is controlled by an "air barrier." An air barrier can be made of anything solid enough to withstand wind pressure such as drywall, plywood and structurally supported polyethylene or olefin fibre sheeting. No matter what functions as your air barrier, it must be as uninterrupted as possible. Try to seal it perfectly airtight. Anything that pierces it — such as electrical outlets, plumbing stacks, exhaust vents, wiring, recessed lights, windows and doors — must be sealed. Theoretically, an air barrier can be installed anywhere in the building envelope, even on the very outside. To avoid damage, however, a more protected position within the building envelope is practical.

Vapour diffusion is controlled by "vapour retarders," which can be made of any impermeable material such as drywall covered with an oil-base or vapour-retarder paint. Sheets of polyethylene are usually used. A vapour retarder should be reasonably well sealed, but taking the time to seal it tightly can make up for unanticipated flaws in your air barrier. A vapour retarder must be installed near the warm side of an insulated space to avoid becoming a cold surface where moisture will condense. It can be placed on the very inside surface of the insulation under the wall finish or it can be located part way into the wall as long as at least two-thirds of the insulation value of the wall occurs outside it. (This is valid in our prairie climate; colder climates require more insulation outside the retarder.)

Figure 2 illustrates the location and function of air barriers and vapour retarders.

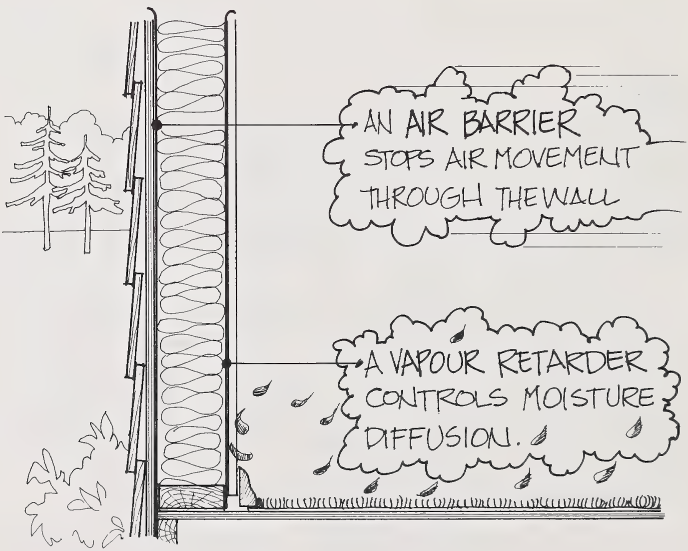


Figure 2 Functions of an Air Barrier and Vapour Retarder

It has become standard practice to seal a home with a combined air barrier and vapour retarder (often called an air/vapour barrier) which serves the double function of stopping vapour diffusion as well as air movement. A combined air barrier and vapour retarder must follow the rules of both. It must be continuously sealed and placed near or on the warm side of the insulation.

Connected decisions

Every energy efficient home should be carefully sealed. Sealing your home affects:

- **Ventilation.** You must have mechanical ventilation in a well-sealed house to prevent the accumulation of pollutants and humidity. Fuel-burning appliances must take combustion air from outside the home to operate safely and properly.

- **Framing systems.** Plan to accommodate the ductwork for a centralized ventilation system in your structure because airtight design requires mechanical ventilation. Framing systems also affect the way your home is sealed with a combined air barrier and vapour retarder. A system that locates the barrier/retarder within an insulated cavity, rather than on the inside of a wall, will protect it from being pierced by wiring or plumbing. Another way to protect your barrier/retarder is to install plumbing and wiring on interior partition walls as much as possible. Roof trusses, which eliminate the need for load-bearing interior partition walls, allow you to install the barrier/retarder in one piece before adding partitions.

- **Size and type of heating system.** A well-sealed house needs less heating capacity than a conventional house and more heating options are practical.

- **Windows.** Airtight design allows higher indoor humidity. You may want windows with more insulation value than usual because they permit higher levels of indoor humidity without condensation.

Ventilation

Principles

Airtight design and centralized mechanical ventilation go together. Centralized mechanical ventilation uses fans to exhaust stale air from your home and to supply fresh air from outside. In a well-sealed house, you need this type of ventilation to maintain good indoor air quality. It also allows control over the warm air exhausted from your home; a conventional leaky home wastes energy by allowing warm air to escape haphazardly and at an excessive rate.

The Alberta Building Code requires new homes to have enough mechanical ventilation to replace half the air in a house every hour (or 0.5 air changes per hour). Have your ventilation contractor size your system appropriately.

Another booklet in this series, **Ventilating Your Home**, describes different kinds of mechanical ventilation systems. Balanced systems that both exhaust and supply air from a central location are the best in our climate. Some, called "heat recovery systems," use a heat exchanger to warm replacement air with exhaust air.

Even with a ventilation system supplying fresh air to the house, furnaces, fireplaces, wood stoves, gas appliances, and water heaters all require separate combustion air intakes. A lit fireplace, for example, must draw combustion air from somewhere; if it doesn't have its own air intake, it may draw air down the water-heater and furnace chimney. This results in a dangerous backdrafting problem, where gases from the combustion of fuel escape into your home instead of going up the chimney.

Even with sophisticated ventilation, it's still nice to be able to open a window. Windows that open can provide summer ventilation and solve a short-term overheating problem from too much solar gain. They are not, however, reliable for proper ventilation.

Connected decisions

The decision to build an energy efficient, well-sealed home means you must have mechanical ventilation. The type of mechanical ventilation you choose will affect:

- **Size and type of heating system.** Any kind of heating system can be installed with any kind of ventilation system. Forced-air heating is convenient to install with balanced mechanical ventilation because the same ductwork can be used to supply heat and fresh air. Your heating system can be smaller if you install heat-recovery ventilation than if you don't.

- **Framing.** The ductwork for ventilation should be planned with your framing. If you combine heat-recovery ventilation with forced-air heating, you will not need separate air-supply ducts. Be sure to locate ducts to avoid the contamination of incoming air with exhaust from furnaces, water heaters or the ventilation system.

- **Windows.** Plan for some openable windows and place them to allow cross currents on the same floor and air movement between floors.

Heating Systems

Principles

It is easy to oversize a heating system in an energy efficient home and important not to. An oversized system will cycle on and off too frequently, wasting fuel and shortening the life of the equipment. The capacity of your heating system should be 10 per cent higher than required to heat your home on the coldest day of the year. To choose a heating system of the right size, ask your contractor to do a heat load calculation.

With only 10 per cent excess capacity, you may find that it takes longer to warm your house on a cold day after setting the thermostat back at night. An automatic setback thermostat will let you turn your furnace on earlier to overcome this problem in very cold weather.

Heating systems available on the market are described in **Selecting a Heating System**, another booklet in this series. You can choose between forced-air and radiant systems at a variety of efficiency levels. In addition to saving fuel, mid- and high-efficiency furnaces and boilers use fans to exhaust combustion products, which eliminates the risk of dangerous backdrafting. The efficiency level that you choose should make

economic sense in your home; the smaller your heating requirements, the longer the payback on higher-efficiency systems.

Connected decisions
Your choice of heating system is affected by airtightness, levels of insulation, degree of solar gain, and type of ventilation system. It affects:

- **Framing systems.** Plan for ductwork if you choose a forced-air heating system and remember that radiant systems will still need ductwork for ventilation. If you choose a floor radiant system, also plan to insulate under the floor to prevent excessive heat loss.

- **Floor plans.** Some heating systems and water heaters do not need vertical chimneys. This will give you more flexibility in floor plans because there is no vertical chimney to locate through all storeys of the house.

Windows

Principles
Windows are weak points in the energy efficiency of your walls because they have a low insulation value and tend to be leaky. At the same time, they can be used to gain heat from the sun. Windows lose heat two ways: by air leaks around the panes and heat flow through the glass. In an energy efficient house, air should not leak between the frame and the wall because this should be well-sealed.

As described in another booklet in this series, called **Windows**, fixed windows are the best for stopping air leaks because they are always sealed. For windows that you want to open, however, choose a design that can be weatherstripped well: casement or awning types are best.

Different glazings have different insulation values. Windows with three panes of glass are better than windows with two because they have an extra dead air space to interrupt heat flow. This means that the inner pane of glass is warmer than in double-pane windows, which reduces condensation. Some new windows are becoming available that achieve energy savings

without the extra pane of glass. Low emissivity (low-e) windows, for example, use a coating that retards the transmission of heat to the outside. Research into new types of windows with high insulation values may someday eliminate constraints on window use in cold climates.

Connected decisions
Airtight design allows higher humidity levels and this can affect your choice of windows. Low-e and triple-pane windows are less prone to condensation problems associated with high indoor humidity. Decisions about windows in turn affect:

- **Degree of passive solar heating.** More windows on the south results in more solar gain. If you are using a lot of south-facing windows to maximize passive solar heating, you may want better than double-pane windows to cut down on heat loss at night. While triple-pane and low-e windows reduce the amount of incoming solar radiation, in our climate they more than make up for it in reduced heat loss throughout the day.

- **Framing.** Decide whether your windows will go on the inside or outside of your framing cavity, which may be wider than conventional construction to accommodate higher levels of insulation. Plan ahead: you may be able to order window frames to match your wall depth.

Framing Options and Details

This section presents some options for framing foundations, walls and ceilings to achieve a well-sealed house with high levels of insulation. They are just some of the techniques used in energy efficient construction. We have chosen them primarily because they are available and current.

Since you would never build an energy efficient foundation, wall or ceiling in isolation, each framing option is presented as part of a total energy efficient house. The combinations we have presented are ideas only. Use the options in different combinations to suit your needs, but remember to balance insulation values and pay attention to principles such as rules for placing vapour retarders inside insulated cavities. The systems are presented in order of increasing efficiency.

System 1

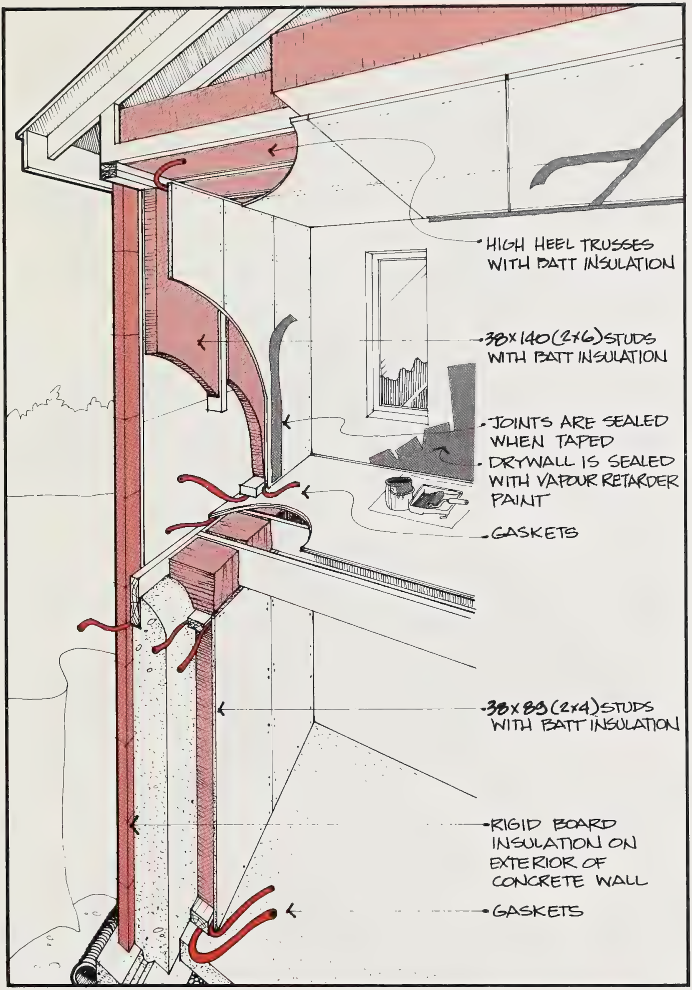
This system illustrates an experimental sealing technique called the airtight drywall approach. Sheets of drywall form the air barrier and vapour retarder. They are sealed against the top and bottom framing plates with closed-cell foam gaskets and joined to each other with tape and plaster. The drywall is then covered with oil-base or vapour-retarder paint.

Concrete foundation insulated inside and outside, RSI 3.5-4.9 (R 20-28)
The basement is framed with 38 mm x 89 mm (2x4) lumber and insulated with batts or sprayed-on cellulose insulation. Rigid insulation is placed on the outside which protects the concrete from ground moisture and large temperature swings.

38 mm x 140 mm (2x6) walls insulated outside with rigid fibreglass, RSI 4.9 (R 28)
The wall is insulated between the studs with batts or sprayed-on cellulose and on the outside with rigid fibreglass. The combined air barrier and vapour retarder is formed with sealed, painted drywall.

Joist space, RSI 1.8 (R 10)
The joist space is insulated with the exterior cladding from the main wall and is sealed with gaskets.

High-heeled roof truss, RSI 7.0 (R 40)
This truss raises the roof rafters up off the top plate allowing an even depth of insulation throughout the attic. In conventional construction, the roof rafters rest on the top plate, restricting the space available for insulation at the eaves.


HIGH HEEL TRUSSES WITH BATT INSULATION
38x140 (2x6) STUDS WITH BATT INSULATION
JOINTS ARE SEALED WHEN TAPED
DRYWALL IS SEALED WITH VAPOUR RETARDER PAINT
GASKETS
38x89 (2x4) STUDS WITH BATT INSULATION
RIGID BOARD INSULATION ON EXTERIOR OF CONCRETE WALL
GASKETS

System 1

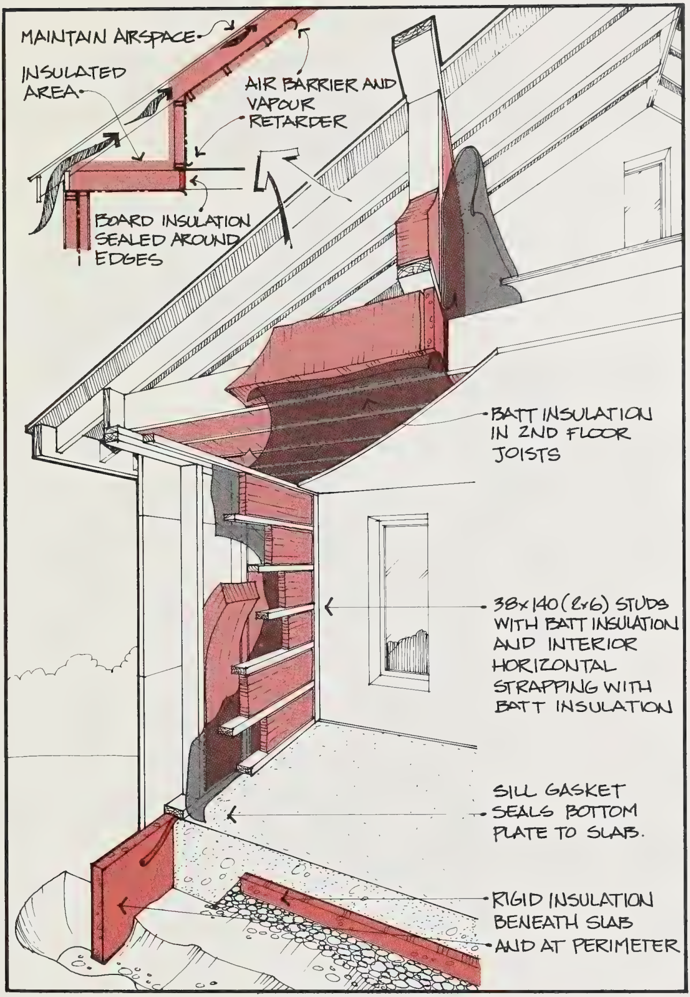
System 2

Since it has no basement, this house incorporates more living space with a storey-and-a-half design. It is consistently strapped on the inside. To strap a wall, extra framing is nailed horizontally onto the main frame. Strapping inside is a convenient way to add insulation to storey-and-a-half construction because of the tight spaces in the sloped section of the ceiling.

Slab on grade with sill-plate gasket, RSI 0.9-1.8 (R5-10)
Comfort is the main reason to insulate a floor. Since all the living area in this house is on the slab, it makes sense. Insulation is placed around the perimeter to reduce heat loss from the side of the slab. The slab is sealed to the bottom plate with a sill-plate gasket made of closed-cell foam, and the combined air barrier and vapour retarder in the main wall is sealed to the bottom plate, making it continous.

38 mm x 140 mm (2x6) wall, strapped inside, RSI 5.3 (R 30)
This conventionally framed wall is cross-strapped with 38 mm x 64 mm (2x3) lumber to create extra room for insulation. The combined air barrier and vapour retarder is in a protected position between the studs and the strapping.

Storey-and-a-half attic strapped inside, RSI 7.0+ (R 40+)
Strapping along the sloped section of the ceiling creates extra room for insulation in a tight place.


MAINTAIN AIRSPACE
INSULATED AREA
AIR BARRIER AND VAPOUR RETARDER
BOARD INSULATION SEALED AROUND EDGES
BATT INSULATION IN 2ND FLOOR JOISTS
38x140 (2x6) STUDS WITH BATT INSULATION AND INTERIOR HORIZONTAL STRAPPING WITH BATT INSULATION
SILL GASKET SEALS BOTTOM PLATE TO SLAB.
RIGID INSULATION BENEATH SLAB AND AT PERIMETER

System 2

System 3

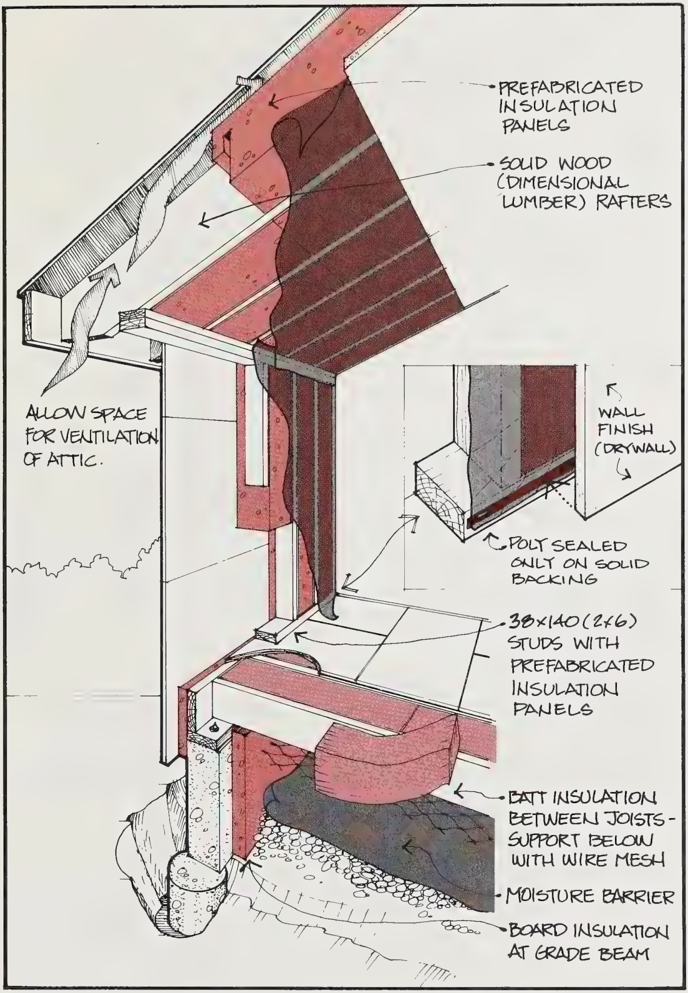
This system has balanced insulation levels. The money saved by building a crawl space instead of a full basement is put toward a more expensive method of insulating the main walls.

Crawl space sealed and insulated under the subfloor, RSI 3.5 (R 20)
In this system, the crawl space is unheated. The foundation walls are insulated to keep temperatures inside the space above freezing. Note that the glued plywood subfloor, which is caulked at the joints and painted with a vapour-retarder paint, functions as an air barrier and vapour retarder. Vents framed into the concrete like windows allow the space to be aired in summer. The vents should be closed in winter to prevent freezing temperatures in the space.

200 mm (8 in.) prefabricated rigid insulation wall panels, RSI 3.5-5.3 (R 20-30)
Some types of these systems come with studs already imbedded in polystyrene insulation. Others supply rigid insulation panels with preformed slots for studs. The rigid polystyrene insulation contributes to the load-bearing capacity of the wall. Although polystyrene insulation has a lower permeability than some insulations, an air barrier and a vapour retarder are still required.

Joist space, RSI 3.5 (R 20)
The joist space is insulated at the same time as the floor.

Strapped cathedral ceiling, RSI 7.0+ (R 40+)
This is a conventionally framed cathedral ceiling with cross-strapping on the inside to make room for more insulation. Note that the combined air barrier and vapour retarder is in a protected position between the rafters and the strapping.


PREFABRICATED INSULATION PANELS
SOLID WOOD (DIMENSIONAL LUMBER) RAFTERS
ALLOW SPACE FOR VENTILATION OF ATTIC.
WALL FINISH (DRYWALL)
POLY SEALED ONLY ON SOLID BACKING
38×140 (2×6) STUDS WITH PREFABRICATED INSULATION PANELS
BATT INSULATION BETWEEN JOISTS - SUPPORT BELOW WITH WIRE MESH
MOISTURE BARRIER
BOARD INSULATION AT GRADE BEAM

System 3

System 4

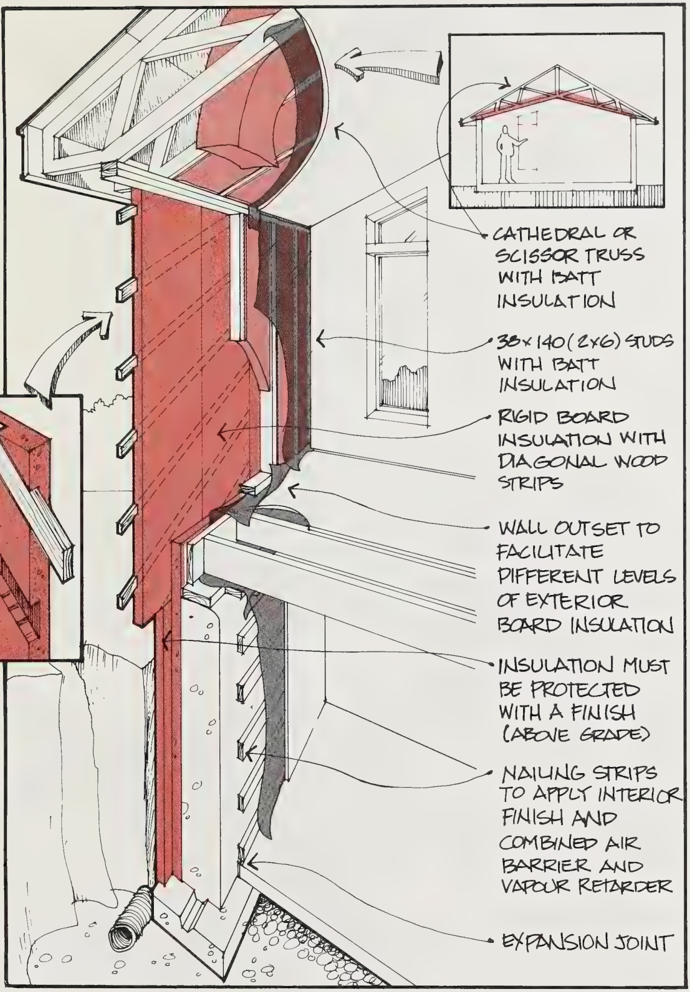
This is a conventionally framed house that has external insulation throughout. It is well-insulated, but not super-insulated.

Concrete foundation, insulated outside, RSI 3.5 (R 20)
Certain rigid insulations can be used on the outside of foundation walls: type-two expanded polystyrene, extruded polystyrene and rigid fibreglass foundation insulation. Finish the insulation above grade to protect it. In this system, the combined air barrier and vapour retarder is on the inside against the concrete. Horizontal 19 mm x 89 mm (1x4) strapping provides a nailing surface for the finish. The strapping can be attached with concrete nails, as shown here, or can be cast-in-place.

38 mm x 140 mm (2x6) wall with polystyrene exterior cladding, RSI 5.3 (R 30)
This is a conventionally framed wall filled with batt insulation or sprayed-on cellulose and covered with rigid polystyrene on the outside. The diagonal strapping inset into the insulation braces the wall and replaces the usual plywood sheathing. It also provides a nailing surface for attaching siding. The main wall is outset 50 mm (2 in.) to make an even outside surface with the basement insulation.

Joist space, RSI 5.3 (R 30)
RSI 1.8 (R 10) rigid insulation from the basement and RSI 1.8 (R 10) from the wall cover the joist space on the outside. An additional RSI 1.8 (R 10) is added from the inside, respecting the rule that at least two-thirds of the insulation value must be on the cold side of the vapour retarder.

Scissor truss cathedral ceiling, RSI 7.0+ (R 40+)
This is a clear-span truss system: it requires no interior wall for support. This allows air barriers, vapour retarders, and drywall to be applied continuously before building interior partition walls. The ceiling joists form a lower angle than the roof rafters, allowing high levels of insulation and good ventilation in the attic.


CATHEDRAL OR SCISSOR TRUSS WITH BATT INSULATION
38×140 (2×6) STUDS WITH BATT INSULATION
RIGID BOARD INSULATION WITH DIAGONAL WOOD STRIPS
WALL OUTSET TO FACILITATE DIFFERENT LEVELS OF EXTERIOR BOARD INSULATION
INSULATION MUST BE PROTECTED WITH A FINISH (ABOVE GRADE)
NAILING STRIPS TO APPLY INTERIOR FINISH AND COMBINED AIR BARRIER AND VAPOUR RETARDER
EXPANSION JOINT

System 4

System 5

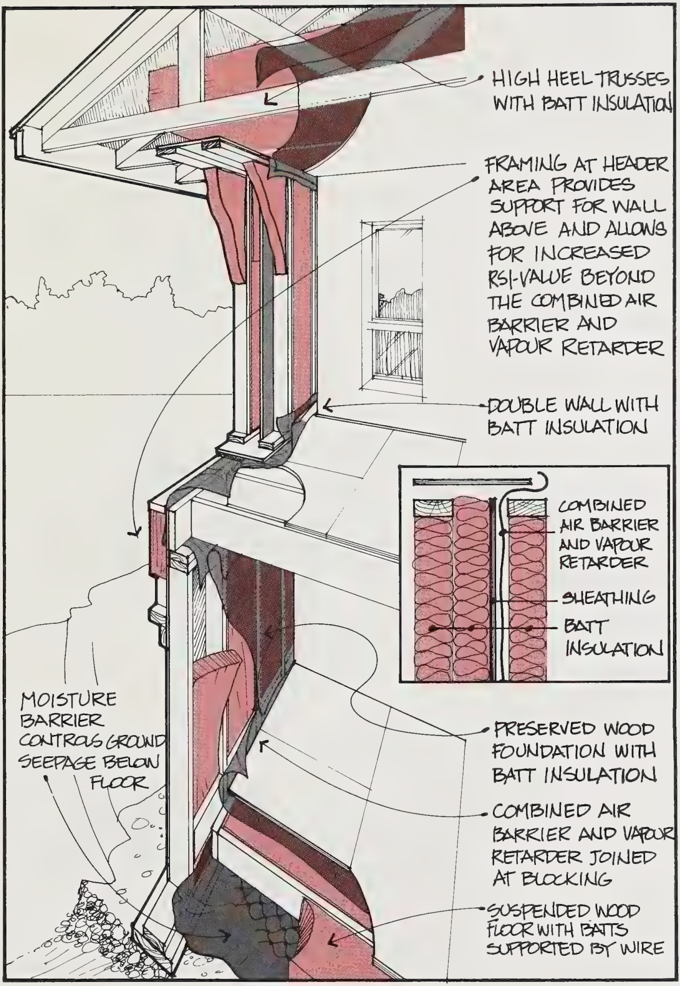
This is a super-insulated design that balances high levels of insulation through all parts of the house.

Wood foundation, RSI 3.5-4.9 (R 20-28) and suspended wood floor, RSI 4.9-6.0 (R 28-34)
Wood foundations are made of pressure-treated wood and framed on the same principles as conventional wood frame construction. This results in ready-made cavities for insulation. A moisture barrier under the wood floor prevents water from migrating into the cavity from the ground. In this system, a combined air barrier and vapour retarder is joined between the wall and the floor at 38 mm x 89 mm (2x4) lumber framed horizontally between the studs around the perimeter of the floor.

Double wall, RSI 7.0+ (R 40+)
A double wall is made of two conventional stud walls connected by plywood top and bottom plates. The total width of the wall, and so the space for insulating, is determined by the width of these plates. Only the inner wall is structural. Note that the combined air barrier and vapour retarder is in a protected position, on the outside of the inner wall underneath the sheathing, and that two-thirds of the insulation value occurs outside it.

Joist space, R 3.2+ (R 18+)
The joist space is framed on the outside with 38 mm x 89 mm (2x4) lumber under the outer layer of the double wall. The framing sits on a ledge above grade. This allows RSI 2.1 (R 12) insulation outside the space and RSI 1.0 (R 6) inside. The space is sealed by wrapping a combined air barrier and vapour retarder around the headers and sealing it to the barrier/ retarders in the main wall and foundation.

High-heeled roof truss, RSI 8.8+ (R 50+)
This system shows a high-heeled truss designed for RSI 8.8 or better.


HIGH HEEL TRUSSES WITH BATT INSULATION
FRAMING AT HEADER AREA PROVIDES SUPPORT FOR WALL ABOVE AND ALLOWS FOR INCREASED RSI-VALUE BEYOND THE COMBINED AIR BARRIER AND VAPOUR RETARDER
DOUBLE WALL WITH BATT INSULATION
COMBINED AIR BARRIER AND VAPOUR RETARDER
SHEATHING
BATT INSULATION
MOISTURE BARRIER CONTROLS GROUND SEEPAGE BELOW FLOOR
PRESERVED WOOD FOUNDATION WITH BATT INSULATION
COMBINED AIR BARRIER AND VAPOUR RETARDER JOINED AT BLOCKING
SUSPENDED WOOD FLOOR WITH BATTS SUPPORTED BY WIRE

System 5

System 6

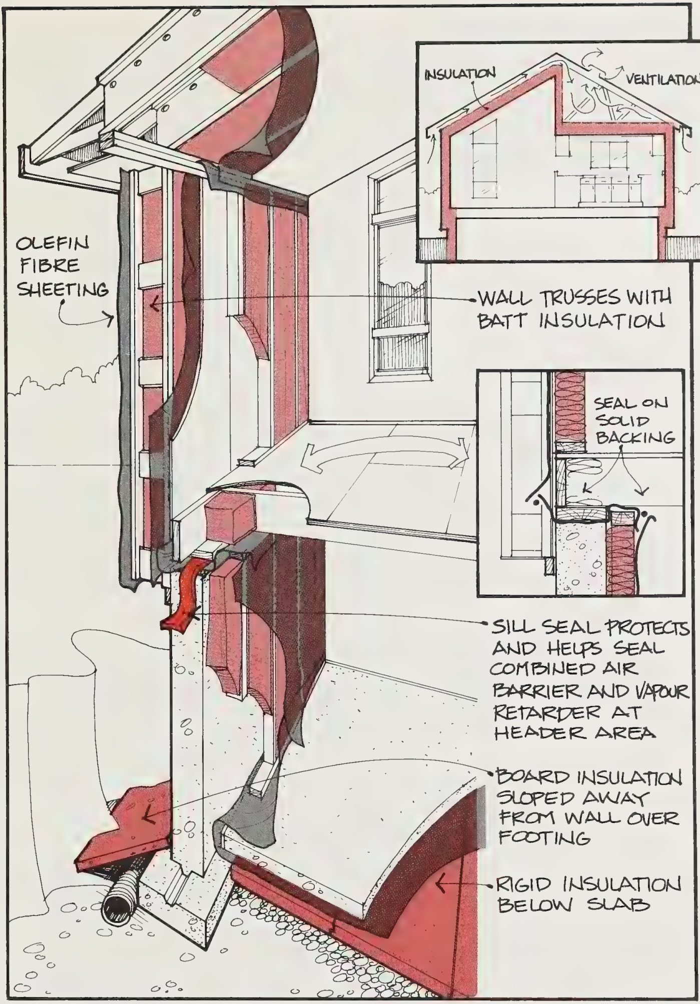
This is another super-insulated design with high levels of insulation throughout. The foundation is insulated on the inside to allow the truss from the main wall to cover the joist space without interference.

Concrete basement insulated inside, RSI 3.5-4.9 (R 20-28), with insulated slab, RSI 1.8 (R 10)
The walls of the basement are framed with outset 38 mm x 89 mm (2x4) lumber and insulated to RSI 3.5 (R 20). Rigid polystyrene insulation is used under the slab. The horizontal insulation outside the slab protects the footings from frost and the weeping tile from clogging with dirt.

Wall truss on 38 mm x 89 mm (2x4) wall, RSI 7.0+ (R 40+)
This is a non-structural truss, added to the outside of a conventionally framed wall, that creates cavities for insulation. The total depth of the wall, and so the insulation level, is determined by the width of the truss. The combined air barrier and vapour retarder is in a protected position in this framing system, between the structural wall and the truss. As in any case where the vapour retarder occurs inside the wall, at least two-thirds of the insulation value is placed outside it. This diagram also illustrates an additional air barrier of olefin fibre sheeting on the outside of the wall.

Joist space, RSI 7.0 (R 40)
The joist space is well-insulated because the truss comes straight down over it from the main wall. It is sealed with a combined air barrier and vapour retarder wrapped under the header and joined with the barrier/retarder from the main wall. A sill gasket protects the barrier from damage by the concrete and fills spaces between the concrete and the sill plate.

Sloped truss cathedral ceiling, RSI 8.8+ (R 50+)
Trusses can be built to allow any level of insulation. This truss is structural and becomes the support for roofing and the interior finish.


INSULATION
VENTILATION
OLEFIN FIBRE SHEETING
WALL TRUSSES WITH BATT INSULATION
SEAL ON SOLID BACKING
SILL SEAL PROTECTS AND HELPS SEAL COMBINED AIR BARRIER AND VAPOUR RETARDER AT HEADER AREA
BOARD INSULATION SLOPED AWAY FROM WALL OVER FOOTING
RIGID INSULATION BELOW SLAB

System 6

Economics

This section looks at the economics of low energy homes by using an example. We have compared the utility and building costs of a particular home built to conventional and energy efficient standards. This economic analysis, of course, ignores the health, comfort and safety advantages of low energy homes.

The example house is a rectangular 108 square-metre (1 160 square-foot) bungalow with a large area of south-facing windows (18.9 square metres or 203 square feet). As a base case, we assume it has an RSI 6.0 (R 34) attic, RSI 3.5 (R 20) walls, a concrete foundation insulated on the inside with RSI 2.1 (R 12) batts, double-pane windows and 0.5 natural air changes per hour. This meets a higher standard than required by the Alberta Building Code but reflects the usual quality of a new home today. Table 2 outlines improvements to the base case, resulting in a well-insulated, but not a super-insulated, house. The second column of Table 2 shows the added costs of the improvements over the base case and the third column lists the corresponding reductions in energy requirements in energy units (gigajoules or GJ). All costs are for Red Deer in 1987 dollars.

You can use these numbers to calculate how long it takes the energy efficient house to pay for itself in energy savings. Simple payback is calculated as the added cost divided by energy dollars saved each year.

$$\text{payback} = \frac{\$\text{ more to build}}{\$\text{ in saved energy/year}}$$

Before you can calculate payback, you need to convert the energy savings listed in column 3 to dollar savings. Column 3 shows units of energy rather than dollars because the amount of money saved depends on your heating system efficiency and the type of fuel it uses. For example, the house in Table 2 saves 74.8 GJ over its conventional version. You need to multiply this by the cost per GJ of the heating fuel. If it's gas and you live in Red Deer, the 1987 price is \$2.53/GJ. You also need to divide by the decimal efficiency of your heating system to account for any fuel it wastes in supplying heat to your home. In this example we assume a conventional 65 per

Table 2
Comparative Costs and Energy Savings of an Energy Efficient House

Base Case	Improved Case	Added Costs	Annual Energy Savings (GJ)	Other Advantages
Foundation: full concrete, RSI 2.1 (R 12)	Foundation: full concrete, RSI 3.5 (R 20) inside	$158	7.9	More comfortable walls
Walls: RSI 3.5 (R 20)	Walls: 38 mm x 140 mm (2x6) with polystyrene exterior cladding, RSI 4.9 (R 28)	$809	6.8	More comfortable perimeter walls
Ceiling: RSI 6.0 (R 34)	Ceiling: RSI 7.0 (R 40)	$112	2.3	Sloped ceiling
Windows: double-pane throughout	Windows: triple-pane throughout	$1 213	24.3	Less condensation, noise transmission reduced
Ventilation: 0.5 natural air changes/hr., no mechanical ventilation	Ventilation: airtight (0.1 natural air changes/hr., 0.25 forced) with heat-recovery ventilation	$1 903	33.5	Better indoor air quality
Totals:		$4 195	74.8 GJ	

cent efficient furnace and so divide by 0.65. If your furnace were 85 per cent efficient, you would divide by 0.85. With electric heating, which is 100 per cent efficient, you would divide by one.

$$\frac{74.8 \text{ GJ} \times \$2.53}{0.65} = \$291.14$$

In our example, the payback of the energy efficient home is:

$$\frac{\$4\ 195}{\$291/\text{yr}} = 14 \text{ years}$$

Note that the added costs of the energy efficient home are about 8 per cent over the base case, assuming the base case costs about $73 000 ($650 per square metre).

The economics of heating systems are also important. **Selecting a Heating System**, another booklet in this series, describes the economics of choosing a new heating system in detail. Here are some general principles. Space heating costs are inversely proportional to heating system efficiency, but higher efficiency systems cost more to buy. The smaller your heating requirements, the longer the payback on higher efficiency units. One way to compare investments is to look at all the costs of different heating systems over time — initial costs, maintenance costs and fuel costs. This is known as a lifecycle cost. Table 3 shows a comparison between a conventional, mid- and high-efficiency gas heating system in an energy efficient house. In this example, there is little difference in total costs over 15 years among a 65 per cent, 70 per cent or 80 per cent efficient furnace.

Table 3
Lifecycle Costs of Different Heating Systems in an Energy Efficient Home

Heating System Type	Initial Costs	Maintenance Costs	Fuel Costs 15 yrs	Total Costs 15 yrs
conventional gas (65% efficiency)	$1 000	$300	$3 000	$4 300
improved conventional (70% efficiency)	$1 200	$300	$2 787	$4 287
mid-efficiency gas (80% efficiency)	$1 600	$300*	$2 436	$4 336
high-efficiency gas (90% efficiency)	$2 500	$300*	$2 166	$4 966

* Maintenance costs are not yet known but may be higher than for conventional furnaces because of complexity.

Small heating requirements increase the attractiveness of fuels other than gas. If you are comparing the economics of different fuels, look at the fixed costs associated with the fuels — such as the capital costs of the heating equipment and the hook-up charges — as well as the actual fuel costs.

Summary

Any house can be energy efficient as long as it incorporates five critical elements: high insulation levels, careful sealing, controlled ventilation, a properly sized and controlled heating system, and attention to window location and design. There are many different ways to incorporate these elements and many different considerations that go into a choice. Economics is only one of them. Comfort, health and safety are key advantages.

Remember that the way you operate your home, no matter how energy efficient, will affect your utility bills. Measures such as setting back your thermostat at night, installing flow restrictors to conserve hot water, and maintaining your furnace and water heater are still important to conserving energy.

Plan an energy efficient home as a system. Each element should be considered in the context of the other elements and follow basic building science principles. Choose framing techniques most convenient and logical for your insulation objectives and the method of sealing your home.

Watch for new products and techniques as experience with energy efficient housing grows.

How To Save Energy